Chapter 1 General

1.0.1 This specification is worked out to facilitate to adopt advanced technology, to be economical and reasonable, to be

safe and applicable and to be of good quality in the design and construction of space frame structures.

1.0.2 This specification is applicable to double-layer grids structure (generally called space frame in this specification) used in the roof and floor system of industrial and civil buildings. The span of roof should not be greater than 120m, and the span of floor should not be greater than 40m.

1.0.3 This specification is worked out in conformity with *Unified standard for design of building structures* GBJ68-84, *General symbols, units and basic terminology used in design of building structures* GBJ83-85, *Load code for the design of building structures* GBJ9-87, *Code for seismic design of buildings* GBJ11-89, *Code for design of steel structures* GBJ17-88, *Code for cold-formed thin-walled section steel structure* GBJ18-87 and *Code for construction and acceptance of steel structure engineering* GBJ205 considering the characters of space frame structure. In the process of design and construction, besides this specification, the *Standard for quality inspection and appraisal of space frame structures* JGJ78-91 and other related codes and standards shall also be complied

with.

1.0.4 The space frames to be subject to high temperature or intensive corrosion, the space frames with fire protection requirements and the space frames of floor subject to dynamic load shall satisfy the requirements of current special codes and standards. The fatigue strength and detailing of space frames which directly bear the suspended crane load of the middle or heavy grade and for which the fatigue check shall be made shall be determined by special tests.

1.0.5 Availability of materials, construction workmanship and fabrication and erection method shall be taken into account in the type selection and detailing of the space frame to achieve the good results of economy and technology. The specifications and types of members and joints of the space frame shall be reduced to facilitate the fabrication and erection.

Chapter 2 General requirements for the design

2.0.1 The following popular types of space frames can be chosen (Appendix one):

1. Two-way rectangular grids, two-way diagonal grids, two-way diagonal oblique grids, three-way grids, one-way mansard grids composed by planar truss (lattice) systems.

2. Square-on-square-offset, square-on-larger-square, square-on-diagonal, diagonal-on-square, rectangle-on-diamond composed by pyramidal units.

3. Triangle-on-triangle-offset, triangle-on-hexagon, honeycomb triangle-on-triangle-offset composed by pyrometric cones.

2.0.2 The type of space frame shall be chosen according to the plane shape, span, support conditions, load, detailing of roof and architectural design of the project. The configuration of the

members of the space frame shall guarantee that unstable geometric system must not occur.

Notes: In this specification, the categorizing of large, middle and small span is made referring to the roof: for large span, 60 meters and above; for middle span, from 30 meters to 60 meters; for small span, less than 30 meters.

2.0.3 As to the space frame with a rectangular planar shape, supported along the sides, when its aspect ratio (long side/short side) is less than or equal to 1.5, diagonal-on-square, square-on-diagonal, square-on-larger-square, two-way diagonal grids, two-way rectangular grids, square-on-square-offset can be chosen. For middle and small span, rectangle-on-diamond and honeycomb triangle-on-triangle-offset can be chosen. When the support spacing is different for two directions, two-way diagonal oblique grids can be chosen.

2.0.4 As to the space frame with a rectangular planar shape, supported along the sides, when its aspect ratio is greater than 1.5, two-way rectangular grids, square-on-square-offset, or square-on-larger-square should be chosen. When the aspect

ration is less than 2, diagonal-on-square can be chosen. When the plane is long and narrow, one-way mansard grids can be chosen.

2.0.5 As to the space frame with a rectangular planar shape, supported along three sides with one side open, the type can be chosen according to Article 2.0.3. For the open side of the space frame, the layers of space frame can be increased or the height of the space frame can be increased. Vertical or oblique side truss shall be formed for the open side.

2.0.6 As to the space frame with a rectangular planar shape, supported at multiple points, according to the actual situations, square-on-square-offset， square-on-larger-square，two-way rectangular grids can be chosen. As to the space frame supported along the sides and at multiple points, two-way diagonal grids or diagonal-on-square can be chosen.

2.0.7 As to the space frame with a circular planar shape, regular hexagon or near regular hexagon and supported along the side, three-way grids, triangle-on-triangle-offset or triangle-on-hexagon can be chosen according to actual situations.

For middle and small span, honeycomb triangle-on-triangle-offset can be chosen.

2.0.8 As to the space frames for the floor with less than 40 meters span in multiple story buildings, and roof with less than 60 meters span, the composite space frame can be chosen, in which the reinforced concrete slabs replace the upper chords. For composite space frame, square-on-square-offset, square-on-larger-square, two-way rectangular grids, diagonal-on-square and honeycomb triangle-on-triangle-offset should be chosen.

2.0.9 The space frame can be supported on the upper chords or the bottom chords and when the bottom chords support method is adopted, the side truss shall be formed along the supporting side.

2.0.10 The dimensions of a grid and height of the space frame can be determined according to the type, span, roofing materials and detailing requirements and architectural functions of the space frame. As to the various space frames supported along the sides, they can be chosen according to Table 2.0.10.

Table 2.0.10 Number of grids of upper chords and span/height ratio of the space frame

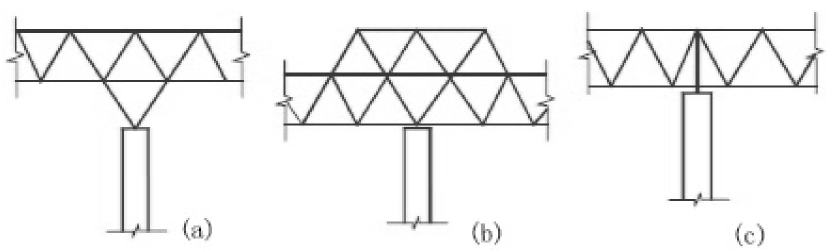
Type	Reinforced concrete roofing system		Steel-purlin roofing system	
	Number of grids	Span/height ratio	Number of grids	Span/height ratio
Two-way rectangular grids, square-on-square-offset, square-on-larger-square	(2~4)+0.2 L_2	10~14	(6~8)+0.07 L_2	(13～17)+0.03 L_2
two-way diagonal grids, square-on-diagonal, diagonal-on-square, rectangle-on-diamond	(6~8)+0.08 L_2			

Notes:

1. L_2 is the shorter span of two ways of the space frame, units in meters.

2. When the span is less than 18m, the number of grids can be reduced.

2.0.11 Column caps shall be set for space frame supported by multiple points. The caps should be set below the plane of bottom chords (Graph 2.0.11a); can be set over the plane of upper chords (Graph 2.0.11b); or the joint of upper chords can be placed directly on the top of column, so the column cap takes on a inverted umbrella shape (Graph 2.0.11c).

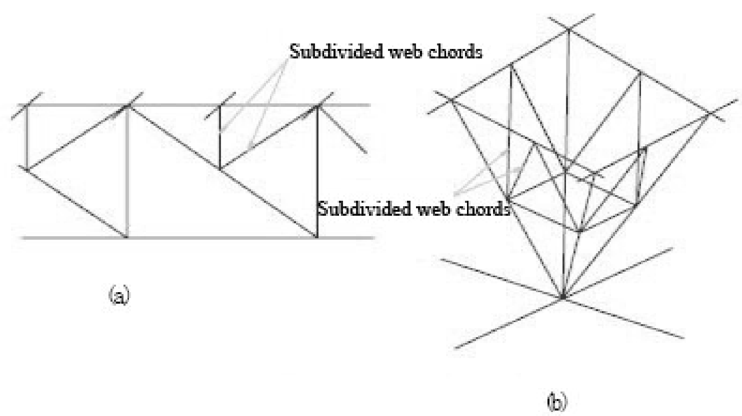


Graph 2.0.11 Setting of the column caps of space frames supported by multiple points

2.0.12 The cantilever length of the space frame supported by multiple points can be one fourth to one third of the span.

2.0.13 Subdivided web chords can be set when there are concentrated loads between the joints of upper chords or the

effective length of compression robs are to be reduced. As to the space frame composed by planar trusses (Graph 2.0.13a) or quadrangular pyramid space frame (Graph 2.0.13b), when subdivided web chords are set, the stability of upper chords outside the plane of subdivided web chords shall be paid attention to.



Graph 2.0.13 The setting of subdivided web chords

(a) For space frame composed by planar trusses;

(b) For quadrangular pyramid space frame

2.0.14 The slope for draining of the roof of the space frame can be set by the following methods:

1. Place small columns on the joints of the upper chords (When the small columns are relatively high, pay attention to the self stability of the small columns);

2. Change the height of the space frame;

3. Sloping the whole space frame;

4. Changing the height of supporting columns.

2.0.15 When cambering is to be set for the space frame, the camber no greater than 1/300 of the shorter span can be set.

2.0.16 The self weight of the space frame g_{ok} (kN/m^2) can be estimated by the following formula:

$$g_{ok} = x\sqrt{q_w}L_2/200$$

(2.0.16)

Where:

q_w--The standard value of the roof load or floor load except the self weight of the space frame (kN/m^2);

L_2--The shorter span of the space frame (m);

x --Coefficient, for space frame made of steel tubes: x =1.0; for

space frame made of steel shapes: x =1.2.

2.0.17 The allowable deflection for the space frame structure shall not be greater than the following value: for roof, L_2/250; for floor, L_2/300, where L_2 is the shorter span.

Chapter 3 Computation of the space frame

Section 1 General principles of computation

3.1.1 The internal forces and displacements of space frame under the action of external loads shall be computed and the internal forces and displacements of space frame under the action of earthquake, temperature variance, support settlement and loads of construction and installation shall be computed according to the actual situations.

As to design without consideration of earthquake action, the loads and their combination shall be computed in accordance with the current national code *Load code for the design of building structures* GBJ9-87. In the design of the sections and joints, the design values of internal forces are determined according the basic combination of the loads; While in the computation of the displacement, the deflection is determined according to the short term combination of loads.

As to design considering the earthquake, the internal forces are determined according to the loads and load combination specified in the *Code for seismic design of buildings* GBJ11-89.

The internal forces and displacements of space frame can be computed in consideration of the elastic stage.

3.1.2 Concentrate the loads within the range of the joint on the joint according to the principle of static equivalence. In structural analysis, the stiffness of the joint can be omitted, and the joint is taken as hinged. So there exit only axial forces for the members. Where there exist local loads on the member, the effect of bending shall be taken into account.

3.1.3 According to the length of span, type and project situations of the space frame, the internal forces and displacements can be computed by the following methods:

1 Space truss displacement method, applicable to the computation of the space frame of various types and of various support conditions.

2 Method of finite difference with intersecting-beam system, applicable to span of less than 40 meters of the space frame composed by planar trusses and square-on-square-offset.

3 Method of slab by analogies, applicable to span of less than 40 meters of the space frame composed by planar trusses or pyramids. This method can take the effect of shear deformation and rigidity variance into consideration.

4 Imaginary moment method, applicable to the estimation of diagonal-on-square, square-on-diagonal.

3.1.4 According to the rigidity of the supporting structure and the detailing of the bearing joints, the support conditions of the space frame can be categorized into: able to move sideways for both ways, able to move sideways for one way, hinged support or elastic support without side movement.

Section 2 Computation principle of space truss displacement method

3.2.1 The space truss displacement method is a method of finite elements method for which the three linear displacements of the joints of the space frame are taken as unknowns, and all the members are taken as hinged which only bear axial forces, and the computation of internal forces and displacements is done by electric computer.

3.2.2 When there exist n symmetrical planes for the structure of the space frame and external loads, the symmetrical conditions can be utilized so only 1/2n of the space frames are needed to analyze. In the process of computation, half of the areas of all members on the plane of symmetry are taken; the 1/2n areas of the central vertical members on the intersection line of the n planes of symmetry are taken; the joint loads on the plane of symmetry are taken in the same manner.

3.2.3 Under the action of the symmetrical loads, the anti-symmetric displacements of the joints of the space frame in

the plane of the symmetry should be taken as zero. During computation, the corresponding direction should be constrained. As to the member intersecting with the plane of symmetry, as a method of solution for the structural analysis, this point of intersection is taken as a joint and is constrained at three directions. When the point of intersection of crossing web members or herringbone web chord lies in the plane of symmetry, it is also taken as a joint and is constrained at two horizontal directions. Under the action of anti-symmetric loads, the symmetrical displacements of the joints of the space frame in the plane of symmetry are taken as zeros.

3.2.4 The sections of the members of the space frame can be determined according to previous experience or by referring to the project already finished or by estimation through the simplified method. After computation, the sections are re-designed and adjusted according to the internal forces, and then the structural analysis is made again. This process should be repeated for 3 to 4 times.

Section 3 Simplified computation method

3.3.1 Through the equivalence of moment of inertia, the space frame composed by planar trusses and square-on-square-offset can be simplified to corresponding intersecting beam system, for which the internal forces and displacements can be computed through the method of finite difference. The equivalence of moment of inertia for the beams can be computed by the following formula:

$$I = \frac{A_t A_b}{A_t + A_b} h^2$$

(3.3.1)

Where:

A_t, A_b--The respective areas of the sections of upper and bottom chords (When the areas of the sections are not equal, the arithmetic average can be taken respectively for the upper and bottom chords in the computation through the method of finite difference);

h--The height of the space frame.

3.3.2 As to the space frame composed by planar trusses, when it is analyzed through the method of finite difference with

intersecting-beam system, the moments of the space frame and the internal forces of the members can be computed according to the following formulas;

$$M_{A,X} = \frac{EI}{s^2}(2w_A - w_{A+1} - w_{A-1})$$

(3.3.2-1)

$$N_t = -\frac{M_{A+1,X}}{h}$$

(3.3.2-2)

$$N_b = \frac{M_{A,X}}{h}$$

(3.3.2-3)

$$N_c = \frac{M_{A+1,X} - M_{A,X}}{s \cdot \sin j}$$

(3.3.2-4)

Where:

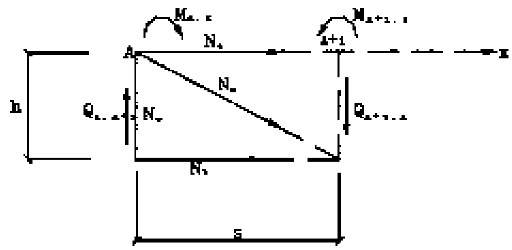
w--The vertical deflection caused by design value of the loads;

h--The height of the space frame;

s--The length of the upper and bottom chords;

j --The angle between the oblique web chord and the plane of bottom chords.

N_v is determined by the equilibrium conditions for the vertical direction of the joints of upper chords (or bottom chords).



Graph 3.3.2 Momemts of the space frame composed by planar trusses and the internal forces of the members

3.3.3 The space frame composed by planar trusses or quadrangular pyramids can be simplified to orthotropic plate or isotropic plate, for which the internal forces and displacements can be computed through the method of slab by analogies.

3.3.4 As to the three types of space frame which include two-way rectangular grids, square-on-square-offset, square-on-larger-square, when the plane shape is rectangular and the space frames are supported along the sides, the internal forces and displacements can be computed by the method of slab by analogies through the following formulas:

$$M_x = \frac{1}{10}(1.2G_k + 1.4Q_k)L_1^2 r_{mx}$$

(3.3.4-1)

$$M_y = \frac{1}{10}(1.2G_k + 1.4Q_k)L_1^2 r_{my}$$

(3.3.4-2)

$$w = \frac{1}{100D}(1.0G_k + 1.0Q_k)L_1^4 r_w$$

(3.3.4-3)

Notes:

1. When the space frame is used for floor and the standard value of live load is not less than 4km/m^2, the coefficient in Formula (3.3.4-1) and (3.3.4-2) shall be taken as 1.3.

2. When there exist two and more live loads, their combination shall be determined according to the national code *Load code for the design of building structures* GBJ9-87.

Where:

w--The deflection under the action of the loads of short term combination;

G_k--The standard value of permanent load of the space frame (kN/m^2);

Q_k--The standard value of live load of roof or floor (kN/m^2);

L_1--The longer span of the space frame;

D--The equivalence bending stiffness of the space frame, which can be determined according to Appendix 2 of this specification;

ρ_{mx}, ρ_{my} and ρ_w--Moment coefficient and deflection coefficient, dimensionless, which can be determined by looking up Appendix 3 of this specification.

The general formulas which change the moment of slab by analogies into the internal forces of the members of the space frame and physical constants of the equivalence bending stiffness of slab by analogies can be determined according to Appendix table 2.1~2.3 in Appendix 3 of this specification. When the areas of cross section of upper chords, bottom chords, oblique chords (bracings), vertical chords, etc are not equal, the arithmetic average of the areas of cross section can be taken respectively.

Section 4 Principle of computing the internal forces under the action of earthquake and temperature

3.4.1 For regions with the earthquake resistance level of 6 or 7 degree, the check calculation for earthquake along the vertical direction for the roof structure of the space frame need not to be made. Whereas for regions with the earthquake resistance level of 8 or 8 degree, the check calculation for earthquake along the

vertical direction for the roof structure of the space frame shall be made.

As to the roof space frame supported along the sides or the roof space frame supported along the sides in combination with the multiple points, the standard value of vertical earthquake action can be determined by the following formula:

$$F_{\mathrm{Evk1}} = \pm y_{\mathrm{v}} \square G_1$$

(3.4.1)

Where:

F_{Evk1}--The standard value of vertical earthquake action acting on the *i* joint of the space frame;

G_1--The character value of the gravity of the *i* joint of the space frame, in which the permanent load is 100% taken while the snow load and dust accumulation load on the roof is 50% taken, further, the live load of the roof is not taken;

y_{v}--The coefficient for vertical earthquake action, determined according to Table 3.4.1.

Table 3.4.1 Coefficient for vertical earthquake action

Earthquake resistance level	Site type		
	I	□	□~□

8	--	0.08	0.10
9	0.15	0.15	0.20

Notes: The site type shall be determined according to the *Code for seismic design of buildings* GBJ11-89.

As to the space frame supported along the sides, the action of vertical earthquake can be determined according to Appendix 4.

As to the roof space frame with a relatively large cantilever span or the space frame used for floor, when the earthquake resistance level is 8 or 9 degrees, the standard value of vertical earthquake action can be taken as 10% or 20% of the character value of the gravity of the structure. In calculating the character value of the gravity, for normal civil building, it can be taken 50% of the live load of the floor.

As to the space frame with very complex plane or very important structure with a large span, mode superposition response spectrum analysis method and time history method can be used to make the analysis for the resistance of vertical earthquake and check calculation.

3.4.2 At regions with earthquake resistance level of 7 degree, the check calculation of horizontal earthquake need not be made to the space frame structure. At regions with earthquake resistance level of 8 degree, the check calculation of horizontal earthquake need not be made to the space frame structure with middle and small spans. At regions with earthquake resistance level of 9 degree, the check calculation of horizontal earthquake need not be made to all types of space frame structures. The internal forces and displacements of the space frame under the action of horizontal earthquake action can be computed by space truss displacement method.

The check calculation of earthquake resistance for the supporting structure of the space frame shall be made according to the relative standards and codes.

3.4.3 When any of these cases occurs, the internal force caused by the temperature variance needs not to be considered:

1. When the detailing of the bearing joint allows the frame structure to move sideways, the value of side movement is equal

to or greater than the value calculated by Formula (3.4.4-1);

2. For the space frame supported along the sides and the span is less than 40m along the direction of check calculation for the space frame, the supporting structure shall be independent columns or web-reinforced brick columns;

3. Under the action of unit load, the displacement on the top of column is greater than or equal to the value computed by the following formula:

$$u = \frac{L}{2x\,EA_m}\left(\frac{Ea\Delta t}{0.038\,f} - 1\right)$$

(3.4.4-1)

If the internal forces caused by the temperature variance need to be considered, space truss displacement method and other approximate methods can be used.

When the detailing of the bearing joints of the space frame constrains the relative movement along the normal direction of the boundary, the horizontal force on the top of columns caused by temperature variance can be computed by the following formulas:

$$H_c = \frac{a \Delta t L}{\frac{L}{x E A_m} + \frac{2}{K_c}}$$

(3.4.4-2)

$$K_c = \frac{3 E_c I_c}{H_c^3}$$

(3.4.4-3)

Where:

K_c--The horizontal stiffness for the cantilever column;

E_c--The modulus of elasticity for the material of the column;

I_c--The moment of inertia for the cross section of the column, the equivalence moment of inertia for the equivalent column is taken in case of frame column;

H_c--The height of the column;

a --The linear expansion coefficient for the materials of the space frame;

E--The modulus of elasticity for the material of the space frame;

f--The design strength of the steel;

L--The span of the space frame along the direction of check calculation;

A_m--The arithmetic average of the areas of the cross section of the chords on the plane of supporting (upper or bottom);

x --Coefficient, when as rectangular grids for the chords on the

plane of supporting, x =1.0; when as diagonal grids, $x=\sqrt{2}$; When as tree-way grids, x =2;

Δt --Temperature difference.

Section 5 Principle for computing the composite space frame structure

3.5.1 The internal forces and displacement of the composite space frame structure can be computed by finite element method. At the time of analysis, discretize the plate with ribs of the space frame into beam elements and shell element which can carry axial force, plane force and moment, take the web chords and bottom chords as the rod element which only carry axial force, and take into account of the characters of two different materials.

3.5.2 The composite space frame structure can also be analyzed by simplification by the space truss displacement method. During analysis, the plate with ribs of the space frame are equalized to upper chords which can only bear axial force, and

compose the equivalence space frame made of two different materials together with the web chords and bottom chords. Then, the internal forces and displacement of the composite space frame structure can be computed by the method of displacement of space truss. The internal force of the section of equivalent upper chords and plate with ribs can be determined according to Appendix 5 of this specification.

Chapter 4 Design and detailing of the members and joints

Section 1 Members

4.1.1 The members of space frame can be made of normal steel shape or thin-walled steel shape. For tubes, the high-frequency electric welded steel pipe or seamless steel tube is used; thin-walled tubular section can be used if conditions agree. The steel for the members shall be used according to the requirements of national standard *Code for design of steel structures* GBJ17-88.

The cross section of the members of the space frame shall be determined by the calculation and check calculation of the bearing capacity and stability.

4.1.2 When determining the slenderness ratio of the members of the space frame, the effective length l_0 shall be determined according to Table 4.1.2.

Table 4.1.2 Slenderness ratio of the members of the space frame

Member	Joints		
	Bolted sphere	Welded hollow sphere	Joints of plate
Chords and web chords at the bearing	l	0.9 l	l
Web chords	l	0.8 l	0.8 l

Notes: l--The geometrical length of the chord (distance between the centers of the joints).

4.1.3 The slenderness ratio of the members of the space frame shall not be greater than the following values:

1. Compression member: 180

2. Tension member

1) Normal member: 400

2) Members near the bearing: 300

3) Members subject to dynamic load: 250

4.1.4 The minimum dimensions for the cross section of members shall be determined by the span of space frame and the size of grid. For normal steel shape, they shall not be less than ∠50×3; for steel tubes, they shall not be less than $f\,48\times2$.

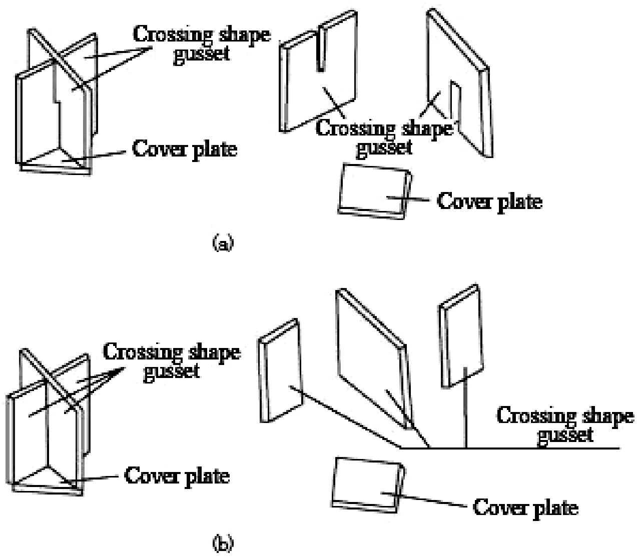
4.1.5 In the design of detailing, dead angle or concave, which make it difficult to inspect, brush, paint and are easy to accumulate humid air or dust, should be avoided. For tubular section, the two ends shall be sealed.

Section 2 Joints of welded steel plate

4.2.1 The joints can be composed by crossing shape gusset and cover plate, suitable for connecting member of steel shape.

The crossing shape gusset can be made by inserting and welding tow slotted steel plates or can be made by welding three steel plates (Graph 4.2.1a, b). As to the tension joint of space

frame of small span, the cover plate need not be set.



Graph 4.2.1 Joints of welded steel plates

The steel used in crossing shape gusset and cover plate shall be the same as that of members of the space frame.

4.2.2 The joint of welded steel plates can be used both for two-way space frame and space frame composed of quadrangular pyramids. The detailing of the popular joints of welded steel plates can be chosen according to Appendix 6 of this specification.

4.2.3 The detailing of the joints of welded steel plates shall

satisfy the following requirements:

1. The gravity lines of the members shall intersect at one point at the joint. Or else, the effect of eccentricity shall be taken into account.

2. The distribution of the welds between the members and joints shall make the gravity center of cross section of the weld coincide with that of the member. Or else, the effect of eccentricity shall be taken into account.

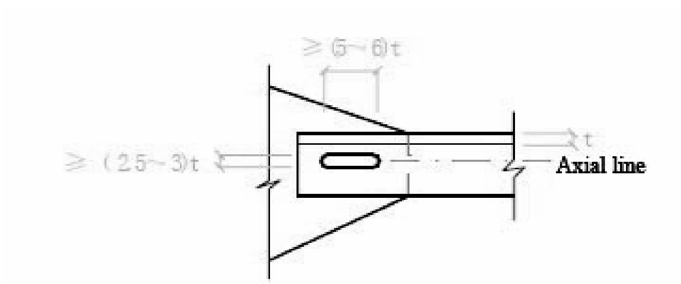
3. Easy to fabricate and assemble.

4.2.4 The chords of the space frame shall be connected both with the cover plate and the crossing shape gusset. When the span of space frame is small, the chords can be directly connected only with the crossing shape gusset.

4.2.5 The thickness of the plate of joint shall be determined according to the maximum internal force of the members of the space frame, and shall be 2mm thicker than the thickness of members connected. Further, it shall not be less than 6mm. The

planar dimensions of the plates of joint shall take the errors of fabrication and assembly into appropriate consideration.

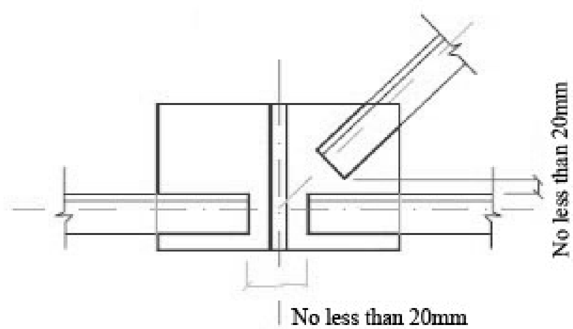
4.2.6 When the members of the space frame are connected with the joints through high strength bolts or fillet welds, the computation shall be made according to the internal forces of the members. Further, the number of joint types should be reduced. When the strength of fillet welds is not enough, the combination of slot welds with fillet welds (the fillet welds as the main connection) can be used if the construction quality can be guaranteed (Graph 4.2.6). And the strength of the slot welds is determined by test.



Graph 4.2.6 Slot welding

4.2.7 The vertical welds of crossing shape gusset shall possess enough bearing capacity, and should be the butted joint with V or K groove.

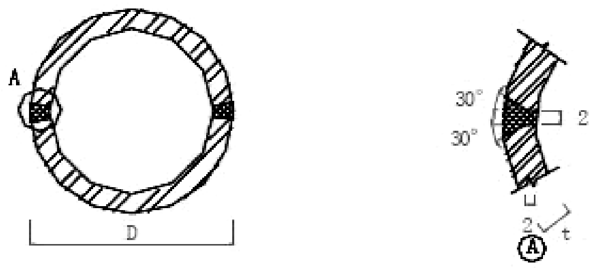
4.2.8 On the joint of welded steel plate, all the gaps between the chords and web chords, between web chords and web chords, and between ends of the chords and the centerline of the joint plate should not be less than 20mm (Graph 4.2.8).



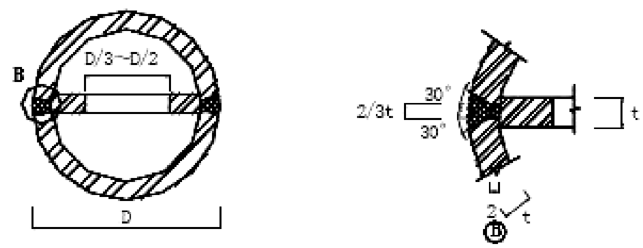
Graph 4.2.8 The detailing of the connecting between the crossing shape gusset and members

Section 3 Welded hollow sphere joint

Article 4.3.1 The hollow sphere composed by welding two half spheres can be categorized into two types: non-stiffened and stiffened, applicable to the connecting of steel tubular members.



Graph 4.3.1-1 Non-stiffened hollow sphere



Graph 4.3.1-2 Stiffened hollow sphere

The hollow sphere should be made of No. 3 steel specified by the national standard *Carbon structural steels* GB700-88 or 16Mn steel specified by the national standard *Technical requirements for low-alloy structure steel* GB1591-88. The quality of product shall satisfy the requirements specified in *Welded hollow sphere joint for steel space frame* JGJ75.2-91.

Boss or flat type rib plate for stiffened hollow sphere can be used. When the boss is used, its height shall not be greater than 1mm.

Article 4.3.2 When the diameter of the hollow sphere is between 120mm and 500mm, the design bearing capacity of compression and tension can be respectively computed by the following formulas:

1. Hollow sphere subject to compression:

$$N_c \le h_c[400td - 13.3\frac{t^2d^2}{D}]$$

(4.3.2-1)

Where:

N_c--The design value of axial compressive force for the hollow sphere subject to compression (N);

D--The outer diameter of the hollow sphere (mm);

t--The thickness of the wall of the hollow sphere (mm);

d--The outer diameter of the steel tube (mm);

h_c--Enhanced coefficient of bearing capacity for the stiffened hollow sphere subject to compression: for non-stiffened h_c=1.0, for stiffened h_c=1.4.

2. Hollow sphere subject to tension:

$$N_t \leq 0.55 h_t t d p f$$

(4.3.2-2)

Where:

N_t--The design value of axial tensile force for the hollow sphere subject to tension (N);

t--The thickness of the wall of the hollow sphere (mm);

d--The outer diameter of the steel tube (mm);

f--The design value of steel strength (N/mm^2)

h_t--Enhanced coefficient of bearing capacity for the stiffened hollow sphere subject to tension: for non-stiffened, h_t=1.0; for stiffened, h_t=1.1.

Article 4.3.3 The ratio between the outer diameter and the thickness of the wall of the hollow sphere can be selected within the range of 25 to 45 according to design requirements; The ratio between the thickness of the wall of the hollow sphere and the thickness of the wall of the steel tube can be selected within the range of 1.2 to 2.0; The thickness of the wall of the hollow sphere should not be less than 4 mm.

Article 4.3.4 In determining the outer diameter of the hollow sphere, the gap *a* on the sphere surface between the connected chords of the space frame should not be less than 10mm (See Graph 4.3.4). To guarantee the gap *a*, the outer diameter of the hollow sphere can be preliminarily estimated by the following formula:

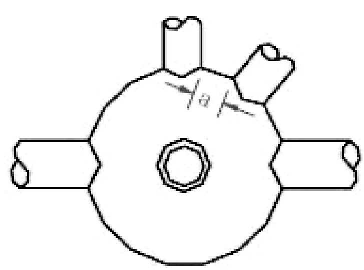
$$D = (d_1 + 2a + d_2)/q$$

(4.3.4)

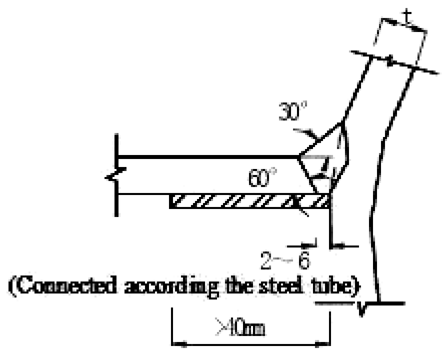
Where:

q --The angle between any two steel tubes chords connected at the sphere joint (rad);

d_1, d_2--The outer diameter of the steel tube forming the angle (mm)



Graph 4.3.4 Hollow sphere joint



Graph 4.3.5 Sleeved connection

Article 4.3.5 When the steel tube chord is to be connected with the hollow sphere, the steel tube should be grooved. A certain gap between the steel tube and hollow sphere shall be reserved and the weld shall be full-penetration to realize the equal bearing capacity of the weld and the steel tube. Or else, it shall be computed as fillet weld. To guarantee the quality of weld, the end of steel tube can be sleeved to weld with the hollow sphere (Graph 4.3.5).

The foot of the fillet weld shall satisfy the following requirements:

1. When $t \leq 4$mm, $h_t \leq 1.5t$;

2. When $t > 4$mm, $h_t \leq 1.2t$;

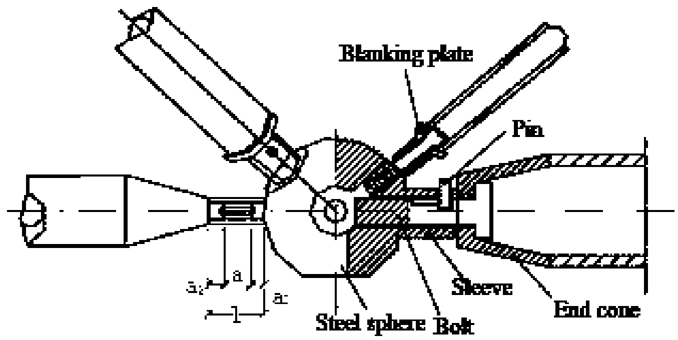
Where t is the thickness of wall of the steel tube, h_t is the

size of the foot.

Article 4.3.6 When the outer diameter of the hollow sphere is not less than 300mm and the internal force of the rod is large, to increase the bearing capacity, ring stiffener with wall thickness not less than that of the sphere shall be added inside the sphere. The chord with relatively large internal force shall lie in the plane of the stiffening plate.

Section 4 Bolted sphere joints

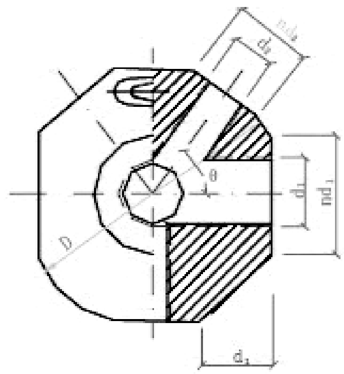
4.4.1 The bolted sphere joint (Graph 4.4.1) is composed by bolts, steel sphere, pin or screw, sleeve and end cone or blanking plate, suitable for connecting the steel tubular members.



Graph 4.4.1 Joint of bolted sphere

4.4.2 The steel tube, blanking plate, end cone and sleeve of the bolted sphere joint should be made of No. 3 steel specified by the national standard *Carbon structural steels* GB700-88 or 16Mn steel specified by the national standard *Technical requirements for low-alloy structure steel* GB1591-88. The steel sphere should be made of No. 45 steel specified by the national standard *High quality carbon structural steel category and technical requirements* GB699-88, the bolt, pin or screw shall be made of 40 Cr steel, 40B steel or 20MnTiB steel specified by the national standard *Technical requirements for alloy structural steel*. The 8.8 s bolt can be made of No. 45 steel. The quality of product shall satisfy the industry standard *Welded hollow sphere joint for steel space frame* JGJ75.2-91.

4.4.3 The diameters of the steel sphere can be determined by the following formula (Graph 4.4.3):



Graph 4.4.3 Bolted sphere

$$D \geq \sqrt{\left(\frac{d_2}{\sin q} + d_1 \mathrm{ctg} q + 2x d_1\right)^2 + h^2 d_1^2}$$

(4.4.3-1)

To satisfy the requirement of contact surface of sleeve, the check calculation shall be made according to the following formula:

$$D \geq \sqrt{\left(\frac{h d_2}{\sin q} + h d_1 \mathrm{ctg} q\right)^2 + h^2 d_1^2}$$

(4.4.3-2)

Where:

***D*--**The diameter of steel sphere (mm);

q --The minimum angle between the two bolts (in rads);

d_1, d_2--The diameter of bolt (mm), $d_1 > d_2$;

x --The ratio between the length of bolt extending into the steel sphere and the diameter of bolt;

h --The ratio between the diameter of circumcircle of the sleeve and the diameter of bolt.

x and h shall be determined respectively according to the design value of tensile force and compressive force that the bolt endures, whose value can be taken as h =1.1, h =1.8.

The larger of the results of two formulas shall be taken as the diameter of the steel sphere.

4.4.4 The high strength bolt shall be chosen from 8.8s or 10.9s specified by the national standard *The high-strength bolts for steel structures* GB1228-91 and shall satisfy the national standard *Basic dimensions of normal bolts* GB193-81 concerning the normal coarse threads.

The design value of tension capacity of each high strength bolt can be computed by the following formula:

$$N_t^b \le y A_{eff} f_t^b$$

(4.4.4)

Where:

N_t^b --The design value of tension force for the high strength bolt (N);

y --The coefficient of influence of the diameter of bolt on its capacity, when the diameter of bolt is less than 30mm, j =1.0; when the diameter of bolt is greater than or equal to 30mm, j =0.93;

f_t^b --The design value of tension strength of the high strength bolt after heat treatment, for 40Cr steel, 40B steel and 20MNTiB steel, take 430N/mm^2; for No. 45 steel, take 365n/mm^2;

A_{eff} --The effective area of cross section for the high strength bolt (mm^2), determine according to Table 4.4.4. When there exists pin hole or keyslot, take A_{eff} as the smaller one of the values at the screw or pin hole or at the keyslot.

4.4.5 The diameter of the bolt connecting the compression members, which is obtained according to the internal forces, can be appropriately reduced. But the sleeve shall be guaranteed to possess enough compression strength. The sleeve shall be computed as carrying compression force and the compression capacity of the place of slot and the effective cross section at the end shall be checked.

Table 4.4.4 Effective areas of cross section at threads for popular bolts

d (mm)	M12	M14	M16	M18	M20	M22	M24	M27	M30
A_{eff} (mm^2)	84.3	115	157	192	245	303	353	459	561
d (mm)	M33	M36	M39	M42	M45	M48	M52	M56	M60
A_{eff} (mm^2)	694	817	976	1121	1306	1473	1758	2030	2362

4.4.6 The outer dimensions of the sleeve shall coincide with the series of the wrench, and the end shall be level and smooth. The inner diameter of the sleeve can be 1mm greater than that of the bolt.

The distance from the end of sleeve to the end of slot shall enable the shearing capacity of the effective cross area here to be no less than that of the pin (or screw), and shall not be less than 1.5 times the width of slot.

The length of the sleeve (mm) can be computed by the

following formula:

$$l = a + 2a_1$$

(4.4.6-1)

$$a = xd_0 - a_2 + d_s + 4\text{mm}$$

(4.4.6-2)

Where:

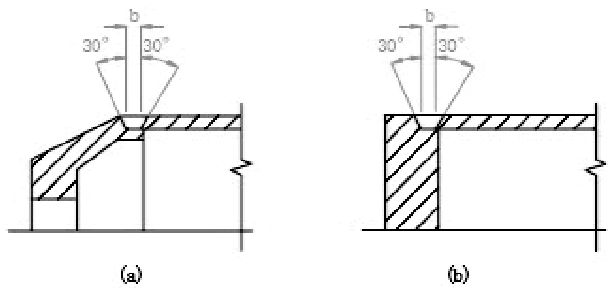
d_s--The diameter of the pin (mm);

a_1--The distance from the end of sleeve to the end of slot (mm);

xd_0--The distance of the bolt extending into the steel sphere (mm);

a_2--The length of the bolt extending out of the sleeve, 4~5mm can be reserved, but no less than 2 threads.

4.4.7 The members can be connected by end cone (Graph 7-a) or blanking plate (Graph 4.4.7-b), whose connecting welds and any cross section of the end cone shall be of the same strength as the steel tubes connected. The width of welds ***b*** can take 2~5mm according to the thickness of the steel tube connected. The thickness of the blanking plate shall be determined by the actual force. When the thickness of the wall of the steel tube is less than 4mm, the thickness of the blanking plate should not be less than one fifth of the outer diameter of the steel tube.



Graph 4.4.7 Connecting weld at the end of the member

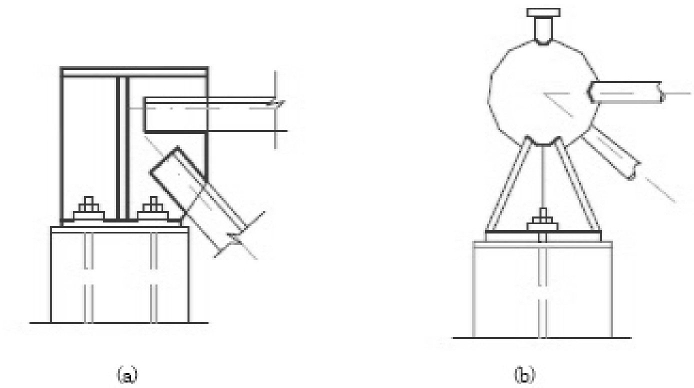
(a) Connecting of end cone with the steel tube;

(b) Connecting of blanking plate with the steel tube

4.4.8 The pin or screw should be made of high strength steel. Its diameter can take 0.16~0.18 times of that of the bolt, and shall not be less than 3mm. The diameter of screw can take 6~8mm.

Section 5 Bearing joint

4.5.1 The detailing of bearing joint shall be selected from the type which can reliably carry the force and is simple to connect and shall satisfy the assumption of calculation.



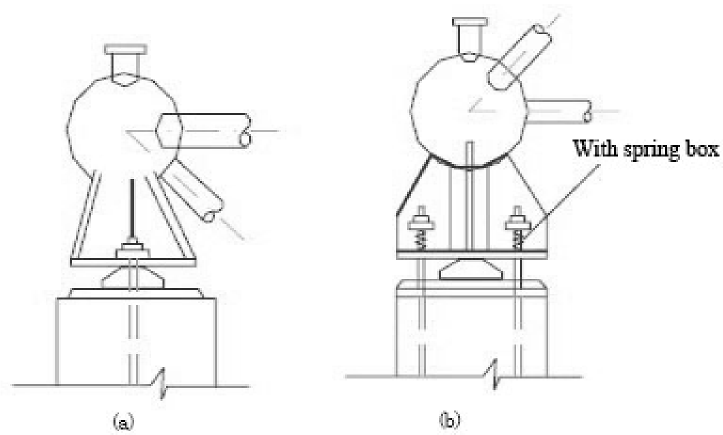
Graph 4.5.2-1 Bearing plate for compression or tension

(a) Member of steel angle; (b) Member of steel tube

4.5.2 The popular bearing joint for compression can be chosen from the following detailing types:

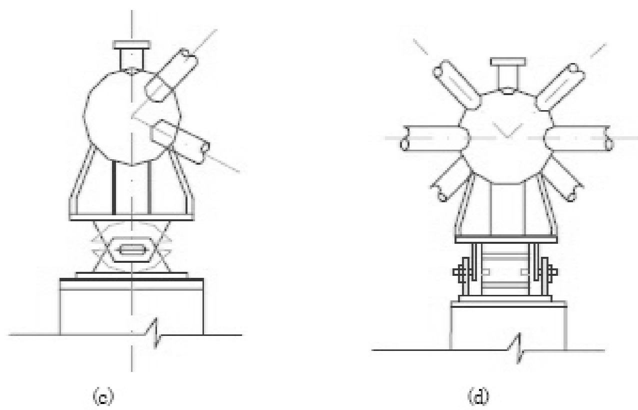
1. The bearing of plate for compression (Graph 4.5.2-1), suitable for space frame with small span.

2. The bearing point with one-way arc plane for compression (Graph 4.5.2-2), suitable for space frame with middle and small span.



Graph 4.5.2-2 The bearing with one-way arc plane for compression

(a) Connected by two bolts; (b) Connected by four bolts



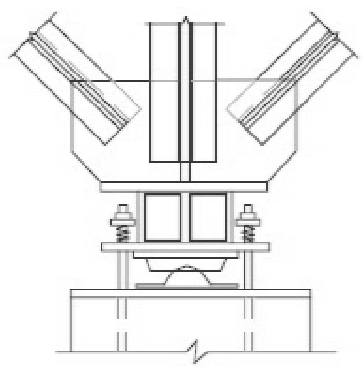
Graph 4.5.2-3 The bearing with two-way arc plane for compression

(a) Side view; (b) Front view

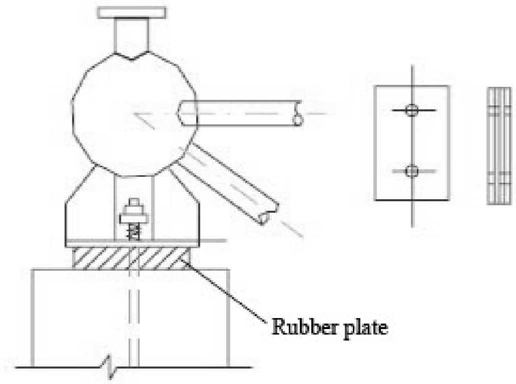
3. The bearing point with two-way arc plane for compression (Graph 4.5.2-3), suitable for space frame with large span.

4. The bearing point with spheric hinge for compression (Graph 4.5.2-4), suitable for space frame with large span supported by multiple points.

5. The rubber bearing point of plate type (Graph 4.5.2-5), suitable for space frame with large and middle span.



Graph 4.5.2-4 Bearing point with spherical hinge for compression

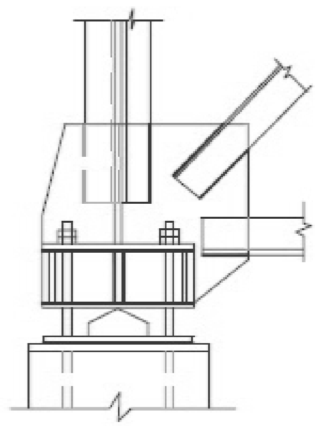


Graph 4.5.2-5 Rubber bearing point of plate type

4.5.3 The popular bearing joint for tension can be chosen from the following detailing types:

1. The bearing of plate for tension (Graph 4.5.2-1), suitable for space frame with small span.

2. The bearing point with one-way arc plane for tension (Graph 4.5.3), suitable for space frame with middle and small span.



Graph 4.5.3 The bearing with one-way arc plane for tension

4.5.4 The arc shape bearing plate should be made of cast steel, and the one-way arc bearing plate can be processed from thick steel plate. The pad for rubber bearing of plate type can be rubber pad made by multiple layers of rubber and think steel plate.

Section 6 Detailing of the joints of composite space frame structure

4.6.1 The joints of the upper chords of the joints of composite space frame structure shall satisfy the following requirements:

1. The reinforced concrete plates with ribs shall be guaranteed to work together with the web chords and bottom chords of the space frame.

2. The axial line of the web chord shall intersect with the center line for the effective cross section of the plate with ribs at the joint.

3. The gusset supporting the reinforced concrete plates with ribs shall effectively transit the horizontal shear force.

4.6.2 The detailing of the joint connecting the reinforced concrete plates with the web chords can be adopted according to Appendix 7 of this specification.

Chapter 5 Fabrication and erection

Section 1 General requirements

5.1.1 The quality of steel shall satisfy the design requirement. If there is no certificate of conformity or there exists question, the test for mechanical properties and chemical analysis shall be carried out according to the current national standard *Code for construction and acceptance of steel structure engineering* GBJ 205. Only after it is proved that the requirements of standard and design are met, can the steel be used. The quality of concrete shall satisfy the requirements specified by the current national standard *Code for construction and acceptance of concrete structure engineering* GBJ 204.

5.1.2 The fabrication and erection of the space frame shall satisfy the *Standard for quality inspection and appraisal of space frame structures* JGJ78-91. The method statement shall be prepared and shall be carried out strictly during construction.

5.1.3 The steel rulers used in the fabrication, acceptance of the space frame and setting out in construction shall be uniform, and the tensile force in measuring shall also be uniform. When the span is relatively large, the temperature correction shall be made according to the temperature.

5.1.4 The welding shall be made in the factory or the yard of prefabrication and assembly to reduce the work in high air or on the field.

On the field, the steel tubes shall be welded by the technical workers over Grade 4. And the examination of welding craftwork at all places for the connection of welded sphere joint with the steel tubes.

When using the welded steel plate joints, the reasonable work process shall be chosen to reduce the deformation and stress caused by welding.

5.1.5 The method of erection shall be determined after considering the features of loading and detailing of the space

frame, after satisfying the requirements for the quality, safety, progress and economy and after considering the local technical conditions for construction.

The installation methods and their application range are as followings:

1. Assembling in the high air. Applicable to all kinds of space frames with bolted joints, suitable for cantilever construction method with a little falsework.

2. Erection by strip or block. Applicable to space frame whose stiffness and loading conditions change little after dividing, for example, Two-way rectangular grids, square-on-larger-square。The size of strip or block shall be determined according to the crane capacity.

3. Slipping in the high air. Applicable to square-on-square-offset, square-on-larger-square, two-way rectangular grids. During slipping, the slipping unit shall be stable geometric system.

4. Hoisting as a whole, Applicable to all kinds of space frames. During hoisting, the space frame can be moved horizontally or rotated to be in place.

5. Lifting as a whole, Applicable to the space frame supported along the side or by multiple points. It can be carried out with small machines and tools, such as plate lifting machine and hydraulic jacking.

6. Jacking as a whole, Applicable to the space frame supported by relatively few points.

5.1.6 When using the erection method of hoisting, lifting and jacking, the choice of the position and number of hoisting points shall take the following factors into consideration:

1. Should be approximate with the loading conditions of the space frame in use.

2. The maximum reaction force at the hoisting points shall no exceed the capacity of the hoisting equipment.

3. The load for each of the hoisting equipment should be close.

5.1.7 After the determination of erection method, the reaction force at the hoisting point, deflection, and internal force of the member, stability of the supporting column during lifting or jacking, and horizontal thrust of the space frame under wind load of the space frame at construction stage shall be checked. Reinforcing measures shall be taken if necessary.

The construction loads shall include the self weight of the structure and all kinds of live construction loads at construction stage. The dynamic coefficient at erection stage: when using lifting or jacking method, take the coefficient as 1.1; when hoisting by pulling bars, take the coefficient as 1.2; when using crawler crane or autocrane, take the coefficient as 1.3.

5.1.8 No matter which kind of construction method is used, before formal construction, the trial assembling and trial erection shall be made. Only when everything works well, can the formal construction be started.

5.1.9 During the construction of the space frame structure, the pollutant such as oxide skin and corrosion on the surface of steel shall be carefully cleaned and anti-corrosion measure shall be carried out in time.

The inner of un-sealed steel tube shall be painted with anti-corrosion paint or other anti-corrosion measures shall be taken. After cleaning the welding slag, the weld shall be painted with anti-corrosion paint.

It is forbidden to increase the cross section or thickness of steel at will for the reason of corrosion.

Section 2 Requirements for fabricating and assembling

5.2.1 The space frame shall be fabricated on special positioner to guarantee the precision of the member and joint and the exchange ability.

5.2.2 The butted welds in the fabrication and assembly of the

space frame structure shall satisfy the Grade 2 for quality inspection and acceptance specified in the current national standard *Code for construction and acceptance of steel structure engineering* GBJ 205. Other welds shall satisfy the Grade 3 for quality inspection and acceptance.

5.2.3 The gusset used in the welded steel plate joints shall be cut by sand machine. The allowable error for length of the gusset is ±2mm, for thickness, ±0.5mm, for angle, ±20'. These can be inspected by angle square and model. The contact surface shall be close.

The half sphere for the welded sphere joint should be grooved by machine. The surface of finished product of sphere after welding shall be smooth and level. There shall not be local bulge or corrugation.

The allowable error for the diameter of the welded sphere: When the diameter of the sphere is less than 300mm, ±1.5mm; when the diameter of the sphere is greater than 300mm, ±2.5mm. Roundness: When the diameter of the sphere is less than 300mm, not greater than 1.5mm; when the diameter of the

sphere is greater than 300mm, not greater than 2.5mm. The thickness reduction of the wall shall not be greater than 13%, and shall not be greater than 1.5mm. The align deviation shall not be greater than 1mm.

There shall not be cracks in the welded sphere joint. The thread shall be processed with 6H precision and shall satisfy the national code *General purpose screw threads-tolerances and fits* GBJ 197-81. The error of distance from the center of the sphere to the surface of the bolt hole should be within ±0.20mm. The allowable error for the angle of bolt hole of the welded sphere is ±30'.

5.2.4 The steel tube of the welded joint shall be cut by machine. The length of the member shall take into consideration of the contraction caused by welding, whose value can be determined by test.

The allowable error for the length of the member fabrication shall satisfy the following requirements:

1. Steel tube member for bolted sphere joint: ±1mm;

2. Steel tube member for welded sphere joint: ±1mm;

3. Steel shape member for welded steel plate joint: ±2mm.

5.2.5 Fractions of the space frame shall be assembled on the special positioner to guarantee the shape and dimensional precision of the small assembly unit.

The allowable error for the unit shall satisfy the following requirements:

1. When the unit is a single pyramidal unit: the length of the chord, height of the pyramidal unit: ±2.0mm; the length of diagonal of upper chords: ±3.0mm; the deviation of the center of the joint of bottom chords: ±2.0mm;

2. When the unit is not a single pyramidal unit, the deviation of center of the joint: 2.0mm;

3. When the unit is a planar truss. The allowable

dimensional error shall satisfy the current national standards *Code for construction and acceptance of steel structure engineering* GBJ 205.

The allowable deviation of the center of the welded sphere joint and the center of the steel tube is 1.0mm.

5.2.6 When the length of unit of the space frame in strip or block is not greater than 20m, the allowable error for the assembly side is ±10mm; when the length of the strip or block is greater than 20m, the allowable error for the assembly side is ±20mm.

As to the space frame supported by multiple points, the allowable error for the assembly side is half of the values specified above.

Trial assembling or other measures can guarantee precision for the assembling in the high air.

5.2.7 Before the general assembly, the precise setting out shall be made for the space frame with welded joints. The allowable errors for setting out are respective 1/10000 of the length of side

and length of diagonal.

The supporting points used in general assembly shall be prevented from uneven settlement.

During general assembling, the reasonable welding procedure shall be chosen to reduce the deformation and stress caused by welding. The assembling and welding procedure shall be from the middle to two ends or four sides.

5.2.8 Appearance inspection shall be made and documented to all the welds of the space frame with welded joints. Non-damage flaw detection shall be made to the butted welds of the tension members and spheres of the large or middle-span space frame made of steel tubes. The number of samples shall not be less than 20% of the total welds. The sampling positions shall be determined by the joint agreement of the designer and the contractor. The quality standard shall satisfy the Grade 2 welds requirements specified in the current national standards *Code for construction and acceptance of steel structure engineering* GBJ 205.

5.2.9 When high strength bolt connection is used in the space frame, after fastening the bolt according to relative requirements, all the gaps shall be caulked tightly by oil loam, and anti-corrosion measures shall be taken according to the requirements of steel structure.

When bolted sphere joint is used in the space frame, after fastening the bolt, all the redundant bolt holes shall be sealed and all the gaps shall be caulked tightly by oil loam before painting anti-corrosion paint two times.

Section 3 Assembling in the high air method

5.3.1 When assembling directly in the high air with small units or members, the procedure shall be able to guarantee the precision of assembling to reduce the accumulated error. When using cantilever method, the structure system which can bear its self weight shall be assembled first before expanding gradually.

During assembling of the space frame, inspect the position of base axial line, elevation, and vertical deviation regularly and make rectification in time.

5.3.2 When assembling the falsework, the position of the top supporting point of falsework shall be set at the joints of the bottom chords. The check calculation of bearing capacity and stability shall be made to the falsework. When necessary, the trial loading shall be made to guarantee safety and reliability.

Measures shall be taken to the parts under the supporting columns of the falsework to prevent settlement of the bearing.

5.3.3 During dismantling the flasework, attention shall be made to prevent the concentrated loading of a few supporting points. The supporting points shall be dismantled by zone, by stage and by proportion in accordance with the deflections of self weigh of the structure at the supporting points. Or it can be dismantled by equal step descending method with each step less than 10mm.

Section 4 Assembling by strip or by block method

5.4.1 When dividing the space frame into strip units or block units and then assembling them into a whole, the unit of the space frame shall be of enough stiffness and shall be geometrically stable, or else temporary strengthening measures shall be taken.

5.4.2 To guarantee the successful assembling of the space frame, at the connecting points of between strip and strip or block and block, measures such as assembling bolts can be taken. When setting up independent supporting points or falsework, the requirements specified by Article 5.3.2 of this specification shall be met.

At the time of closing, the jack can be used to jack the unit of space frame to design elevation before connecting.

5.4.3 The intermediate transport of the unit of the space frame should be avoided. When transport has to be done, measures to prevent the deformation of the space fame shall be taken.

Section 5 Sliding in the high air method

5.5.1 The following two methods can be used for the slipping in the high air method:

1. Single strip slipping. Slip the single strip along the sliding track preset to design position before assembling;

2. Sliding after accumulating by strip. The units of space frame by strip are accumulated and assembled on the slide track before sliding to design position.

For sliding in the high air method, the structure already built can be used as platform for assembling in the high air. If there does not exist structure for this purpose, the assembling platform with a width of two units can be set at the start of the sliding.

If conditions agree, strip units or block units can be

assembled on the ground before lifting to the assembling platform for assembling.

5.5.2 The sliding track can be fixed by the pre-embedded parts on the top of reinforced concrete girder, the elevation the track surface shall be higher than or equal to the design elevation of the bearing of the space frame.

The joints of the slide track shall be tightly caulked. If connected by welds, the welds above the surface of the track shall be filed to smooth. If the bearing plate slides directly on sliding track, it two ends shall be filleted. There shall not exist barrier at two sides of the sliding track.

The friction surface shall be coated with lubricant.

5.5.3 When the span of the space frame is relatively large, the sliding track should be additionally set under the middle span. The flasework under the sliding track shall satisfy the requirements in Article 5.3.2 of this specification.

5.5.4 When horizontal direction guiding wheels are set, they

shall be set at the inner side of the sliding track. The gap between the direction guiding wheels and the sliding track shall be within 10~20mm.

5.5.5 The sliding of space frame can be hauled by fairleader or hand hoist. According to the 大小 of the hauling force and chords between the bearings of the space frame, it can be hauled at one point or multiple points. The speed of hauling should not be greater than 1.0m/min, the hauling force can be checked according to rolling friction and sliding friction by the following formula:

1. Sliding friction

$$F_{t} = m_{1} \cdot x \cdot G_{ok}$$

(5.5.5-1)

Where:

F_t--The total starting hauling force;

G_{ok}--The standard value of the self weight of the space frame;

m_1--The coefficient of sliding friction, for the rolled surface, 0.12~0.15 can be taken between steel and steel after complete rust removing and lubrication;

x--The coefficient of resistance force, when there are other

factors to influence the hauling force, 1.3~1.5 can be taken.

2. Rolling friction

$$F_t \geq (\frac{k}{r_1} + m_2 \frac{r}{r_1}) G_{ok}$$

(5.5.5-2)

Where:

F_t--The total starting hauling force;

G_{ok}--The standard value of the self weight of the space frame;

k--The rolling coefficient between the steel wheel and steel, 0.05 mm can be taken;

m_2--The friction coefficient is between the wheel and the axle, or after maching and complete lubrication, 0.1 can be taken between steel and steel;

r_1--The radius of outer circle of the wheel (mm);

r--The radius of the axle (mm).

When sliding the space frame, the asynchronizing of the two ends shall not be greater than 50mm.

5.5.6 In the process of sliding and assembling, the follow check calculation shall be made to the space frame:

1. When there does not exist supporting point in the middle span, the internal forces of the members and the deflection in the mid-span.

2. When there exists supporting point in the middle span, the internal forces of the members, the resistance at the supporting point, and the deflections.

When the sign of the internal forces of the members of the sliding unit of the space frame changes because of the setting of middle supporting point, temporary strengthening measures shall be taken to prevent buckling.

Section 6 Hoisting as a whole method

5.6.1 The space frame can be hoisted by a pulling bar or multiple pulling bars, or be hoisted in place by one or more hoisters.

When multiple pulling bars are used, the unequal

horizontal component forces caused by the pulley blocks at the side of the pulling bar can be used to move or rotate the space frame in place (Graph 5.6.1).

The force analysis of the hoisting equipment can be made according to the tension force of the pulley blocks. At the hoisting stage or in-place stage, the tension force of the pulley blocks can be computed by the following formulas:

Hoisting stage: (Graph 5.6.1a)

$$F_{t1} = F_{t2} = \frac{G_1}{2\sin a_1}$$

(5.6.1-1)

In-place stage (Graph 5.6.1c)

$$F_{t1}\sin a_1 + F_{t2}\sin a_2 = G_1$$

(5.6.1-2)

$$F_{t1}\cos a_1 = F_{t2}\cos a_2$$

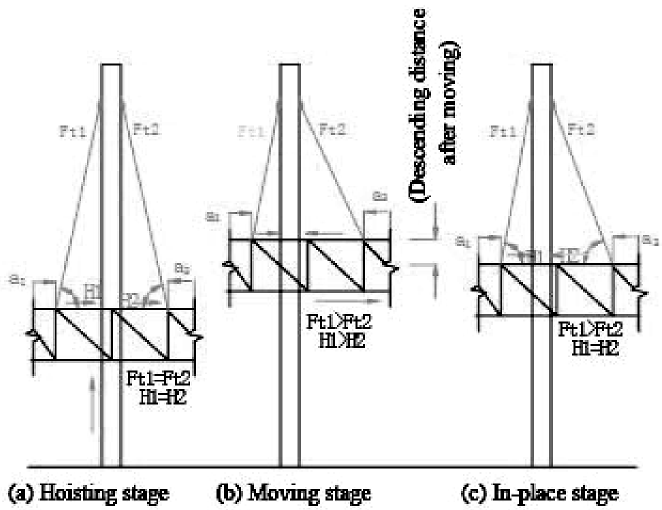
(5.6.1-3)

Where:

G_1--The load of space frame and rigging that each pulling bar carries;

F_{t1}, F_{t2}--The tension force of the pulley blocks;

a_1, a_2--The angle between the steel wire rope of the pulley blocks and the horizontal plane



Graph 5.6.1 Sketch of the moving of the space frame in the air

The relationship between moving distance (or rotation angle) of the space frame and the descending distance of the space frame can be determined by graphic method or by calculation.

When hoisting by a pulling bar, for rectangular space frame, the cable wind rope can be adjusted to move the space framed hoisted by the pulling bar in place; for regular polygon or circular space frame, by rotating the pulling bar, the space frame

can be rotated in place.

5.6.2 When hoisting the space frame as a whole, the lifting and descending of the hoisting points shall be at the same phase. The allowable elevation difference (the relative elevation difference between the two neighboring pulling bars or between the resultant forces of two hoisting points group) is 1/400 of the distance of hoisting points and should not be larger than 100mm. Or it can be determined by test.

5.6.3 When a few pulling bars or a few hoisting machine are used to hoist the space frame, the rated load shall be multiplied by the reduction coefficient 0.75. But when four hoisting machine are used to hoist the hoisting points in two groups or three pulling bars are used to hoist, the reduction coefficient can be appropriately increased.

5.6.4 In making the plan of general assembling and moving in place, the following shall be satisfied:

1. The net distance between any part of the space frame and the supporting columns or pulling bars shall not be less than

100mm.

2. If there exists projecting structure on the supporting column (for example, corbel), be careful not to be blocked by the projecting structure in the process of hoisting the space frame.

3. For the reason of misalignment of the space frame, a few members are not assembled for the moment; it shall need the approval of the designer.

5.6.5 pulling bar, cable wind rope, rigging, ground anchor, foundation and the composing of the pulley stock for hoisting， shall be checked by calculation. If necessary, test inspection can be carried out.

5.6.6 When hoisting by multiple pulling bars, the pulling bars shall be vertical. The tensile force of the cable wind rope in the initial should be 60% of that at hoisting stage.

5.6.7 When hoisting by single pulling bar, its base shall use spherical universal joint; when hoisting by multiple pulling bars,

in the hoisting plane of the pulling bar, one-way hinged joint can be used. Under the most unfavorable loads combination, the compression force exerted by the supporting foundation shall not be greater than the bearing capacity of the subsoil.

5.6.8 If the self bearing capacity of the space frame structure allows, the pulling bars can be removed by using the pulley blocks set on the space frame.

Section 7 Lifting as a whole method

5.7.1 The space frame can be lifted by the lifting equipment installed on the structure or can be lifted at the same time with the sliding formwork for the columns construction, when the space frame can work as operating platform.

5.7.2 The working load capacity is got by multiplying rated load with reduction coefficient. For through type hydraulic jack, 0.5~0.6 can be taken; for electric screw plate lifting machine, 0.7~0.8 can be taken; for other equipment, this coefficient is

determined by test.

5.7.3 The lifting of the space frame shall be at the same step. The maximum allowable difference between two neighboring lifting points or between the highest and the lowest lifting points shall be determined by check calculation. The allowable difference between two neighboring lifting points: when using plate lifting machine, 1/400 of the distance between neighboring points, and shall not be greater than 15mm, when using through type hydraulic jack, 1/250 of the distance between neighboring points, and shall not be greater than 25mm. The allowable difference between the highest and the lowest lifting points, when using plate lifting machine, is 35mm; when using through type hydraulic jack, is 50mm.

5.7.4 The point of resultant force of the lifting equipment shall coincide with the lifting point. The allowable deviation is 10mm.

5.7.5 In the lifting a whole method, the supporting column below shall be checked for stability.

Section 8 Jacking as a whole method

5.8.1 When jacking the space frame as a whole, As many as possible supporting columns shall be used as supporting structure in jacking. Temporary falsework for jacking can also be set at the original supporting points or their neighboring places.

5.8.2 The spacing of the batten plate on the supporting columns or the temporary falsework shall be integral number of times of the working range of the jack. And the deviation of the elevation of the batten plate shall not be greater than 5mm, or else, it shall be padded to level with thin steel plates.

5.8.3 The screw jack or hydraulic jack shall be used for the jacking jack, whose working capacity is got by multiplying the rated load with reduction coefficient. For screw jack, 0.6~0.8 can be taken; for hydraulic jack, 0.4~0.6 can be taken.

The range and lifting speed shall be the same for all the

jacks. The jack and their hydraulic system shall be checked on the field before use.

5.8.4 The difference between the jacking points during jacking shall satisfy the following requirements:

1. 1/1000 of the distance between two neighboring supporting structures for jacking use, and shall not be greater than 30mm;

2. When there exist two or more jacks on the same supporting structure for jacking use, 1/200 of the distance between the jacks, and shall not be greater than 10mm.

5.8.5 The center of jack or the resultant force of the jacks shall coincide with the centerline of the column. The allowable error is 5mm. The jacks shall be vertical.

5.8.6 Before jacking and during jacking, the horizontal deviation of the center of the bearing of the space frame from the centerline of the column shall not be greater than 1/50 of the shorter side or 1/500 of the height of the column.

5.8.7 The check calculation of the stability of the supporting structure for jacking use shall be made. In check calculation, besides the self weight of the space frame and supporting structure, other static loads and construction load jacked together with the space frame, the effect of the eccentricity of the loads and wind load shall also be taken into consideration. If the capacity of stability is not enough, construction measures shall first be taken.

Section 9 Construction of composite space frame structure

5.9.1 The allowable errors for the dimensions of the prefabricated reinforced concrete slabs and the quality of concrete shall satisfy the requirements in the current national standard *Code for construction and acceptance of concrete structure engineering* GBJ 204.

5.9.2 The micro-expansion cement shall be used in mixing the caulking concrete. The placement shall be made without break.

Only the strength of caulking concrete achieves 75% of the strength grade of the concrete, can the falsework be removed. The quality standard of concrete is the same as those specified in Article 5.9.1 of this specification.

5.9.3 The allowable dimensional errors for the fabrication and assembly of the steel web chords and bottom chords of the composite space frame and requirements for welds quality shall satisfy the requirement in Section 2 of this chapter.

5.9.4 The assembling method for the composite space frame structure can adopt: assembling in the high air, hoisting as a whole, jacking as a whole, by strip (by block), and slipper in the high air.

When the composite space frame is divided into strip (block) units, the check calculation shall be made to the bearing capacity and stiffness of the units. The deflection of the units shall not be greater than the deflection here after the whole structure is formed.

Section 10 Acceptance

5.10.1 Every procedure of fabrication, assembly and erection of the space frame shall be inspected and accepted. Without inspection and acceptance, the next procedure must not be started. After erection, the finial inspection and acceptance shall be made. The record for the inspection and acceptance of each procedure shall be made and shall be summed up to store.

There shall be certificates of conformity and inspection records for the welded spheres, bolted spheres, members, high strength bolts, etc.

5.10.2 At finial acceptance, the deviation of the length of the longitudinal and transverse sides and deviation of the center and height of the supporting points shall be inspected. The allowable deviation for the longitudinal and transverse sides is 1/2000, and shall not be greater than 30mm; The allowable deviation for the center of the supporting points is 1/3000 and shall not be greater than 30mm, The allowable deviation for the height of the

supporting points is: For the neighboring points of the space frame supported along the side, 1/400 of the distance between two neighboring bearings, and shall not be greater than 15mm, and the difference between the highest and lowest points is 30mm; For the neighboring points of the space frame supported by multiple points, is 1/800 of the distance between two neighboring bearings, and shall not be greater than 30mm.

5.10.3 After construction, the deflection of the space frame (including the deflection of the self weight of the space frame and the deflection after finishing the roof system). The average of the deflection measured shall not be 15% greater than design value, and the deflection curve measured shall be documented. The observing points for the space frame are: for small span, one point at the middle of the bottom chords; for large and middle span, five points, which are one point at the middle of the bottom chords, two points each for the quarter points of the span of bottom chords. For three-way space frame, the deflections at three of quarter points for every way span shall be measured.

5.10.4 The following files shall have been prepared at the

acceptance of the space frame: working drawings for the space frame, as-built drawings, files of design modification, method statements, the quality certificate and test reports of the steel and other materials used; the certificate of conformity and test reports of the parts of the space frame, the acceptance record for the procedure of assembling, certificate of the welder examination, the test reports of the quality of the welds and high strength bolts, the records of the geometrical errors and deflections after in place.